U.S. GOVERNMENT SUPPORT OF THE ENTREPRENEURIAL SPACE AGE

SPACE ANGELS®

EXECUTIVE SUMMARY

The modern space economy was built upon 60 years of technology development funded largely by the government.[1] Today, business model innovation is putting that technology into the hands of entrepreneurs, stimulating competition, and creating a dynamic marketplace. From the launch of Sputnik in 1957 until 2009, there were two dozen privately funded commercial space companies that had raised non-governmental equity financing globally.[2] Everything changed July 2009, when SpaceX launched its first commercial payload—a 50kg Earth observation satellite for Malaysia— which flew into space aboard a privately developed rocket. With transparent pricing and lower launch costs, SpaceX has increased access to the space economy for new entrants. Since 2000, the number of privately funded space companies has grown to 375 with nearly $19 billion of private capital invested into those companies (a 13.8x increase).[3] This period, from 2009 to present, is what Space Angels refers to as the Entrepreneurial Space Age.[4]

But, while SpaceX began as a lone venture by an aspirational entrepreneur, the success of the company is the result of a collaborative effort with NASA.[5] Indeed, SpaceX operated on total funding of approximately $1 billion in its first ten years of operation, about half of which came from progress payments on government contracts. Following the company's successful first mission of their Dragon capsule to the International Space Station in 2012, SpaceX CEO Elon Musk showed his appreciation for his government partners, stating at a press conference after the launch, "I would like to start off by saying what a tremendous honor it has been to work with NASA. And to acknowledge the fact that we could not have started SpaceX, nor could we have reached this point without the help of NASA."[6]

Government funding has played a role in the development of the Entrepreneurial Space Age and continues to shape its future. By supporting development and acting as a customer of SpaceX, the government has helped address a barrier to entry and increased access to the space economy through low-cost, reliable, commercial launch. This paper describes how the government continues to fuel the growth of the Entrepreneurial Space Age in established industries like Launch, while supporting new companies in emerging industries like Logistics and Interplanetary (see Table 1).

The purpose of this research is to better understand the relationship between the United States (U.S.) Government and these newer space companies, particularly focusing on the sources, tools, and impact of public funding. The major findings from this report include:

- The total value of U.S. public funding received by entrepreneurial space companies from 2000 through 2018 was $7.2B across 67 companies.

- Public funding has played an important role in supporting an entrepreneurial approach to space, particularly in addressing the barriers to entry, with 93% of U.S. Government funding flowing into the Launch industry.

- NASA is supporting technology development and providing early customer traction across the space economy. While the vast majority of public funding from U.S. Government agencies has focused on the Launch industry, NASA has also awarded funds to companies in the Biospheres, Industrials, and Interplanetary industries.

- Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs awards are the most common forms of public funding for entrepreneurial space companies that are eight years and younger, accounting for 44% of all awards. This funding acted as a source of non-dilutive, early-stage capital and has provided over $135M in public funding across 345 unique awards to 35 companies located in 27 different U.S. states between 2002 and 2018.

- Department of Defense (DOD), Department of Energy (DOE), and NASA's SBIR / STTR programs tend to support entrepreneurial space companies earlier in their life cycle.On average, the 35 companies who received SBIR/ STTR funding attracted $6 in private investmentfor every $1 of public funding. Comparatively, the complete set of 67 entrepreneurial space companies that received awards from the government averaged $1.1 of private investment for every $1 of public funding.

- NASA and the DOD have awarded, on average, 2% and 1% of their annual SBIR / STTR budget to equity-backed entrepreneurial space companies, respectively.

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1. Space, The Final Economic Frontier, Journal of Economic Perspectives, Matthew Weinzierl, Spring 2018
2. Proprietary Data, Space Angels, September 30, 2018
3. Proprietary Data, Space Angels, September 30, 2018
4. Entrepreneurial Space Age Began in 2009, Ars Technica, Eric Berger, October 31, 2017
5. Rethinking Public-Private Space Travel, Space Policy Journal, Chad Anderson, 2013
6. Not So Private Space: The SpaceX-NASA Partnership is Blasting Off, Good, Lizzie Wade, May 25, 2012

- There are 123 equity-financed space companies that have registered for a Data Universal Numbering System (DUNS) number but have yet to secure public funding.

As governments around the world prioritize their space capabilities, they are working with the private sector to build a sustainable space economy[7]. By providing critical early funding for new companies in emerging industries like Logistics, the U.S. Government is supporting the growth of space infrastructure, such as Space Situational Awareness (SSA). Similarly, through programs like Commercial Lunar Payload Services (CLPS), the U.S. Government supports the development of new industries in the space economy.

This report represents an effort to establish an initial understanding of the role the U.S. Government has played in supporting an entrepreneurial approach to space. The findings in this report help illuminate the government's mission, public policy, and U.S. competitiveness in space.

This initial research was limited in its scope and, as such, there is further opportunity to expand upon the findings uncovered here. Areas for potential future research include:

1) Explore different types of support not covered in this report including technology transfer, government equity investments (e.g. In-Q-Tel), strategic hiring by entrepreneurial firms, and reimbursable as well as non-reimbursable support;

2) Evaluate state and local initiatives designed to attract or enable space activities;

3) Analyze international programs designed to support the advancement of their national space industries.

METHODOLOGY

DEFINITIONS

The following definitions enabled us to identify, associate, and analyze the data underlying this report:

"Commercial" – private sector enterprises that bear a significant portion of investment risk and responsibility for activities and operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment.[8]

"Entrepreneurial" – a commercial entity that has raised non-governmental equity financing to deliver a product or service.

"Early-Stage" – a commercial entity with a maximum equity investment round of $10M or less.

"Growth-Stage" – a commercial entity with a maximum equity investment round greater than $10M and less than or equal to $80M.

"Late-Stage" – a commercial entity with a maximum equity investment round greater than $80M.

"Industry Segmentation" – A Space Angels-developed industry segmentation, based on an assessment of the current landscape of space business activity and informed by the 2015 NASA Technology Roadmap[9] (see Table 1).

"Public Support" – U.S. Government support takes various forms, including direct financial support, non-reimbursable support, and technology transfers; however, for the purpose of this report, only those monetary forms of support were considered.

"Space Company" – a commercial entity that participates in one of the industries outlined in Table 1.

"Space Economy" – refers to the full group of industries outlined in Table 1.

"Time Horizon" – the years 2000 through 2018 (Q3) to capture the formation, financing, and growth of a sample consistent with our definition of an Entrepreneurial Space Company provided above.

7. China Increases Investment in Emerging Private Space Industry, CNBC, October 10, 2018
8. National Space Policy, Office of Space Commerce, 2010
9. 2015 NASA Technology Roadmaps, Office of the Chief Technologist, Accessed 15 February 2019

TABLE 1 - INDUSTRY SEGMENTATION

INDUSTRY	SECTOR	DESCRIPTION
Launch[10]	Small Launch	Systems for launching payloads of up to 2,000 kg; includes suborbital and near-space vehicles; includes entry and landing systems.
	Medium Launch	Systems for launching payloads of 2,000 – 20,000 kg; includes entry and landing systems.
	Heavy Launch	Systems for launching payloads of 20,000 – 50,000 kg; includes entry and landing systems.
	Super Heavy Launch	Systems for launching payloads of 50,000+ kg; includes entry and landing systems.
	Launch Brokerage	Access to launches based on the manifests of multiple providers; may also assist with regulatory adherence and payload integration.
	Spaceport Operations	Launch infrastructure and logistics.
Satellites	Earth Observation	Manufacture and/or operations of satellite(s) whose primary focus is remote sensing; includes data, analytics, and software products.
	Communications	Manufacture and/or operations of satellite(s) whose primary focus is communication; includes data, analytics, and software products.
	Positioning, Navigation, Timing (PNT)	Manufacture and/or operations of satellite(s) whose primary focus is PNT; includes data, analytics, and software products.
	Manufacturing & Components	Design and/or manufacture of satellite(s) and/or components, including operating software.
	Operations & Ground Segments	Third party operators of satellite(s); ground operations (gateways and terminals) that receive signals from satellite(s).
Industrials	Energy Generation, Distribution, & Storage	Energy with in-space applications. Storage and transfer, at an industrial level, in any medium.
	Extractives	Prospecting and mining of resources in space, including the surfaces of asteroids.
	Manufacturing, Construction, & Maintenance	In-space manufacturing and construction, using resources sourced terrestrially or in space. Includes collection, processing, and reuse or disposal of waste materials.
Logistics	Space Situational Awareness (SSA)	Information delivery regarding the space environment, particularly hazards to both in-orbit and ground infrastructure.
	Debris Mitigation	Solutions to mitigate debris from the mass of defunct, artificially created objects in space including old satellites and spent rocket stages, as well as the fragments from their disintegration and collisions.
	On-Orbit Servicing	Spacecraft refueling and repairs.
Biospheres	Habitats	Design, construction, and operations of facilities intended to support life for short and long-term periods
	Spacesuits	Design and/or manufacture of suits designed for both Inter-Vehicular Activities and Extra-Vehicular Activities (IVA and EVA).
	Spaceflight Training	Training conducted terrestrially, but designed to prepare participants for in-space travel and living.
Interplanetary	Landers & Rovers	Robotics developed for use on other celestial bodies.
	Deep Space Satellites	Comms, PNT, and Remote Sensing satellites designed for missions beyond Earth orbit.
	Deep Space Communications	Comms across deep-space networks, or point-to-point comms between two in-space spacecraft; includes internet access for viewership in-space.
	Deep Space Positioning, Navigation, & Timing	Relative and proximity navigation, onboard auto navigation and maneuver, timekeeping and time distribution.
Information & Research	Scientific Research & Platforms	Microgravity research, science instruments, observatories, in-situ instruments and sensors; computation and modeling.
Media & Education	Culture & Design	Consumer products for the promotion of space.
	Early Development & Training	Educational programs using space hardware and/or data.

10. NASA Space Technology Roadmaps – Launch Propulsion Systems, p.11 "Small: 0-2t payloads, Medium: 2-20t payloads, Heavy: 20-50t payloads, Super Heavy: >50t payloads"

AUTHORS

Space Angels is an early-stage investor specializing in space startups.[11] Founded in 2007, the company has made 27 investments in the space economy.[12] Space Angels maintains a database of all non-government equity investments in commercial space companies, for the purpose of uncovering insights about investing. This data is gathered from a number of sources across many categories. No single piece of data can be added to the database until confirmed by multiple sources. The results are published regularly in the Space Angels Space Investment Quarterly, which is referenced multiple times throughout this report.

MATERIALS

The report focuses on two key participants: entrepreneurial space companies and the U.S. government agencies that are funding them. Space Angels has invested in several of the companies that will be mentioned in this report. From here onward, all companies that are a part of Space Angels portfolio will be denoted with an asterisk (*) at the first mention of the company.

This research was conducted using Space Angels' proprietary dataset of privately funded space companies and combined with public funding datasets (see Tables 2 and 3) and surveys (created for this study) of entrepreneurial space companies.

TABLE 2 - DEPARTMENTS AND AGENCIES

Source: Small Business Innovation Research, Federal Procurement Data System, and USASpending.gov

DEPARTMENT NAME	ACRONYM	AGENCY NAME	ACRONYM
Department of Commerce	DOC	National Oceanic and Atmospheric Administration	NOAA
Department of Defense	DOD	Defense Advanced Research Projects Agency	DARPA
Department of Defense	DOD	U.S. Strategic Command	STRATCOM
Department of Defense	DOD	U.S. Air Force/Air Force Research Laboratory	USAF/AFRL
Department of Defense	DOD	U.S. Army	ARMY
Department of Defense	DOD	U.S. Navy	NAVY
Department of Defense	DOD	Missile Defense Agency	MDA
Department of Energy	DOE	-	-
Department of Homeland Security	DHS	Federal Emergency Management Agency	FEMA
Department of Interior	DOI	Earth Resources Observation and Science	EROS
Department of Justice	DOJ	Federal Bureau of Investigation	FBI
Department of State	DOS	-	-
Department of Transportation	DOT	Federal Aviation Administration	FAA
Government Services Administration	GSA	Federal Acquisition Service	FAS
-	-	National Aeronautics and Space Administration	NASA

11. Betting on the Moon: The Most Active Space Tech Investors, CBInsights, May 2, 2017
12. Space Angels. Crunchbase. Accessed May 30, 2019

TABLE 3 - AWARD TYPES

Source: Small Business Innovation Research, Federal Procurement Data System, and USASpending.gov

AWARD TYPE	DESCRIPTION
Contract	Cost Plus, Definitive Contract, Firm Fixed, Indefinite Delivery, R&D
Purchase Order	Delivery Order, Federal Supply Schedule, Purchase Order
Grant	NIAC, DARPA, National Science Foundation, Training, Research
Cooperative Agreement	Federal Government provides funding or support authorized by public statute and the government plays a substantial role.
Other Transactions (OT)	Special authority used by some federal agencies, including the DoD and NASA, for obtaining or advancing research and development or prototypes; NASA's OT's are called Space Act Agreements.

DESIGN

This report focuses on the years 2000 through 2018 to capture the founding and early development of several entrepreneurial launch companies that have been instrumental in lowering the barriers to entry for other startups through transparent pricing and lower cost access to space. The analysis focuses on companies that successfully attracted non-governmental equity financing as a minimum threshold for credibility of their business model and market opportunity. This report does not consider those companies that have relied entirely on debt financing or other methods given the limited information available on these transactions. The data used in this report is only an indication of the observations and early patterns emerging between the U.S. Government and entrepreneurial space companies and will require a longer history and larger sample size to draw definitive conclusions. This leaves a wide variety of further research to be conducted, particularly as the space economy continues to evolve and mature.

There are multiple instances throughout this report where the full data sample is compared to a subset where the Launch industry has been removed. Space Angels chose to present the information in this way because Launch data is comparatively large in value thereby distorting, or hiding, other trends.

PROCEDURE

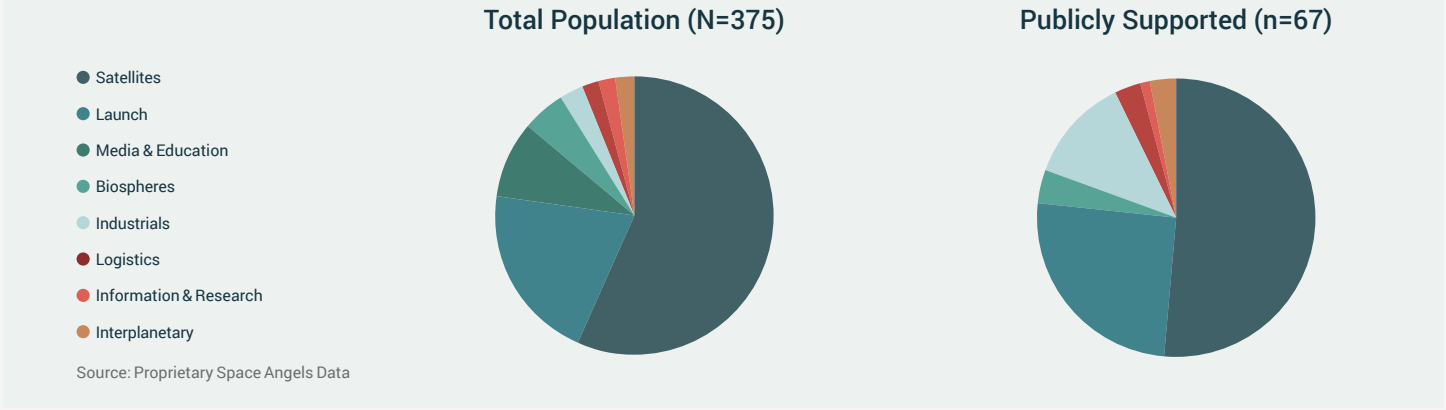
The population for this research began with Space Angels' proprietary dataset composed of 375 privately funded space companies globally, each of which has been confirmed against multiple sources (including investment databases, private transactions, and confidential sources) before being added to the sample.[13] This population was then refined based on the steps shown below. The resulting list was used to develop a public funding dataset, which was primarily sourced from Small Business Innovation Research (sbir.gov), Federal Procurement Data System (fpds.gov), and USASpending.gov, as well as through direct conversations with private companies.

Step 1: 375 equity-funded space companies globally from 2000 through Q3 2018
Step 2: 212 companies identified in the United States with private funding data
Step 3: 190 companies identified with DUNS numbers to cross reference with public data
Step 4: 67 companies identified having secured public funding

The broad sample generated in Step 4 is the foundation of the findings presented in this paper. The 67 publicly funded company representative of the population with the primary difference being a slightly larger proportion of Launch and Industrial companies, slightly fewer Satellite companies and no Media & Education companies.

The sample from Step 4 was combined with additional data to support additional analysis. Each data set is identified throughout the research by referencing the following:

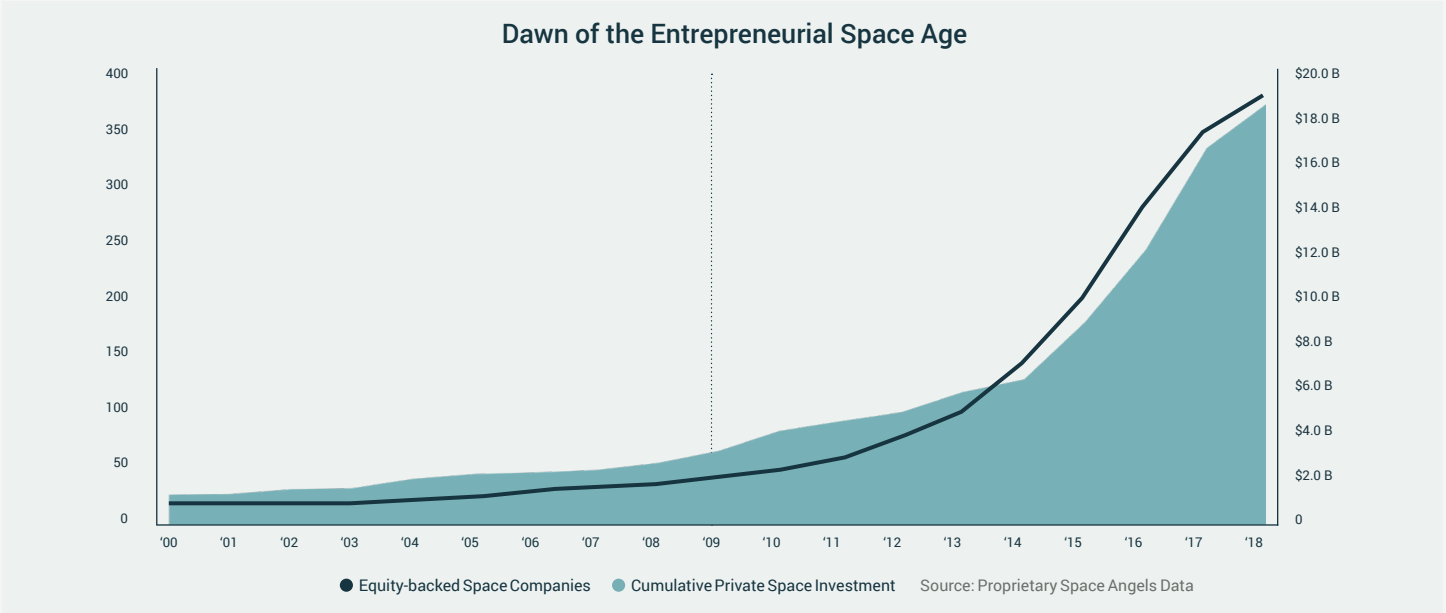
13. Space Investment Quarterly, Q3 2018, Space Angels, October 9, 2018



- "Public Awards & Contracts" – This data set includes 67 sample companies and 782 awards and contracts that provide a broad overview of public funding
- "Public Awards, Contracts, & Modifications" – This data set includes 63 sample companies with 1,273 awards, contracts, and modifications to provide additional detail into public funding
- "Public & Private Funding" – This data set includes 52 sample companies overlaid with 674 private funding events to provide additional insight into public and private funding

BACKGROUND

The modern space economy was built upon 60 years of technology development funded largely by the government. Today, business model innovation is putting that technology into the hands of entrepreneurs, stimulating competition, and creating a dynamic marketplace. From the launch of Sputnik in 1957 until 2009, there were two dozen privately funded commercial space companies that had raised non-governmental equity financing globally.[14] Then, in July of 2009, SpaceX* launched its first commercial payload—a 50kg Earth observation satellite for Malaysia—which flew into space aboard a privately developed rocket. With lower prices and transparent pricing, SpaceX has increased access to the space economy for new entrants. Since 2000, the number of privately funded space companies has grown to 375 with nearly $19 billion of private capital invested into those companies (a 13.8x increase).[15] This includes the period from 2009 to present, which Space Angels refers to as the Entrepreneurial Space Age.[16]



14. Proprietary Data, Space Angels, September 30, 2018
15. Space Investment Quarterly, Q3 2018, Space Angels, October 9, 2018
16. Entrepreneurial Space Age Began in 2009, Ars Technica, Eric Berger, October 31, 2017

PUBLIC FUNDING ANALYSIS

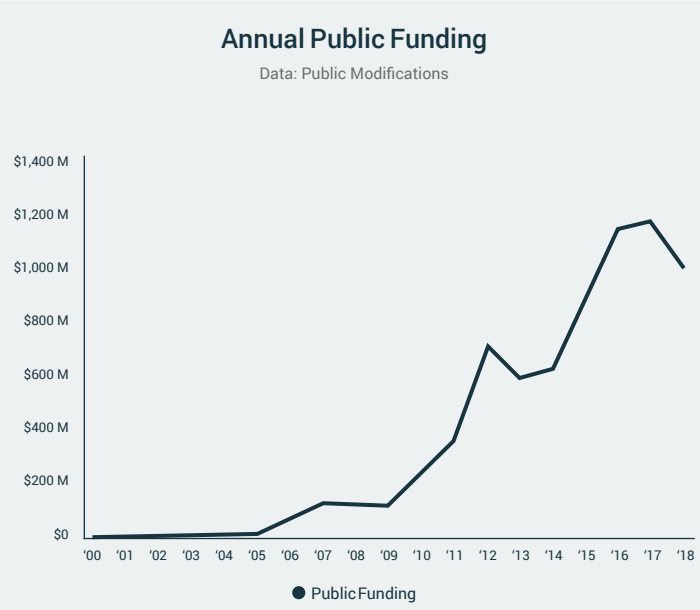
The U.S. Government has a long legacy of partnering with private companies to access and develop the space economy. During the time frame of this research, and particularly over the past eight years, a wave of entrepreneurial activity has reshaped the established Launch and Satellites industries and helped to develop new industries. To better understand the relationship of public funding and emergence of entrepreneurial activity, Space Angels analyzed a sample of 782 unique awards and nearly $7.2B in public funding associated with 67 companies (see Table 4).

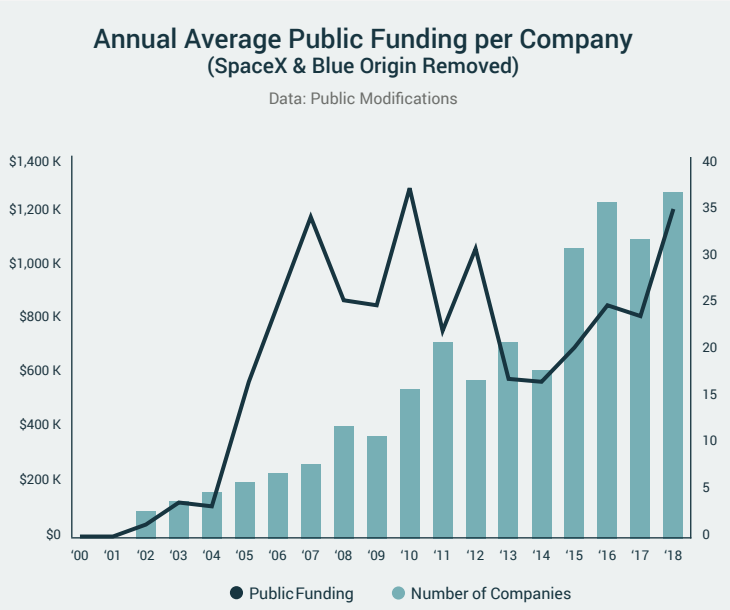
TABLE 4 - GOVERNMENT AGENCIES

Data: Public Awards & Contracts

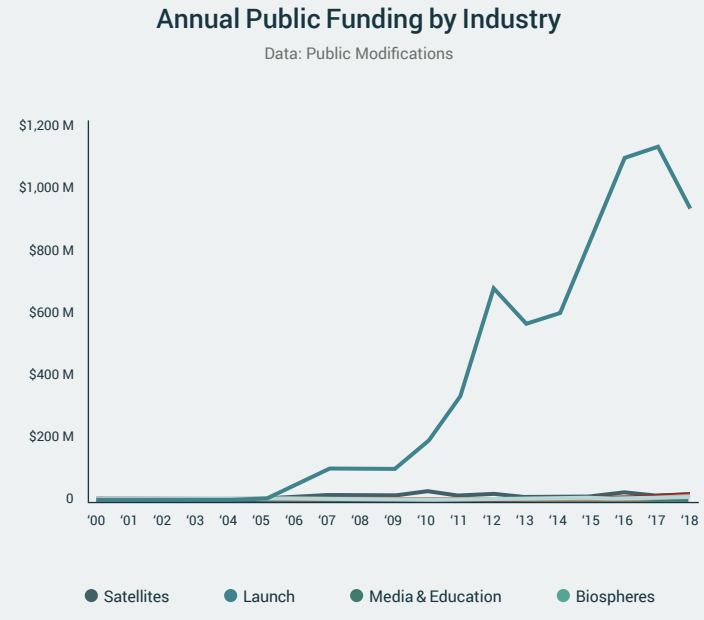
AGENCY	NUMBER OF AWARDS	TOTAL VALUE	AVERAGE VALUE	UNIQUE COMPANY COUNT	SHARE OF TOTAL AWARDS	SHARE OF TOTAL VALUE	TOP AWARD TYPE
NASA	330	$6,109.4M	$18.5M	49	41.8%	85.4%	IDC
USAF/AFRL	123	$874.0M	$7.1M	22	15.6%	12.2%	DCA
DOS	1	$62.8M	$62.8M	1	0.1%	0.9%	IDC
DARPA	28	$29.6M	$1.1M	14	3.5%	0.4%	FFP
ARMY	83	$19.8M	$0.2M	9	10.5%	0.3%	DCA
MDA	38	$23.1M	$0.6M	6	4.8%	0.3%	FFP
NAVY	34	$15.9M	$0.5M	10	4.3%	0.2%	FFP
DOE	14	$5.1M	$0.4M	2	1.8%	0.1%	FFP
FAA	5	$2.7M	$0.5M	3	0.6%	0.0%	FFP
DOI	9	$2.6M	$0.3M	5	1.1%	0.0%	FFP
NOAA	8	$2.4M	$0.3M	5	1.0%	0.0%	FFP
FAS	9	$2.0M	$0.2M	9	1.1%	0.0%	FSS
FEMA	3	$0.9M	$0.3M	1	0.4%	0.0%	FFP
DHS	2	$0.9M	$0.4M	1	0.3%	0.0%	PO
FBI	7	$0.6M	$0.1M	3	0.9%	0.0%	FFP

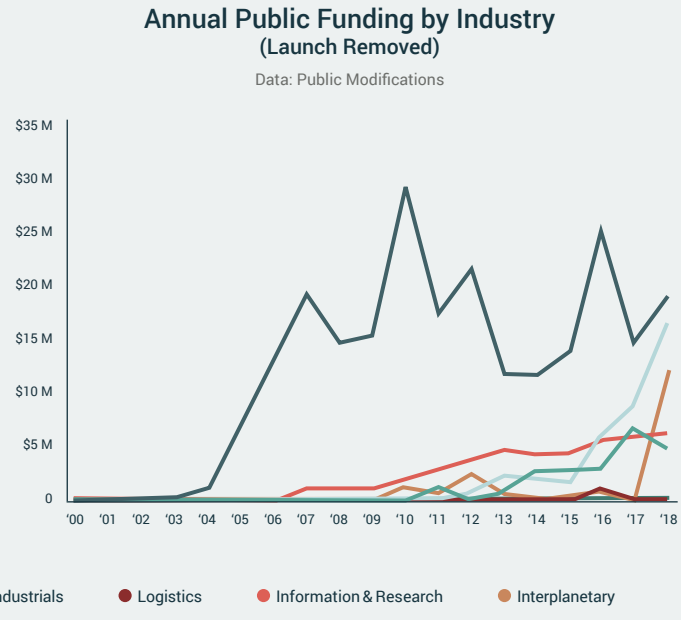
Looking at the top 15 public departments and agencies providing funding, Space Angels finds that NASA, the U.S. Air Force (USAF), and the U.S. Army were the most active in terms of share of total awards, accounting for 68% collectively. NASA and the USAF were the largest in terms of a departments' share of total value, representing 98% of all funding deployed from 2000 through 2018. It is important to note that multiple companies received awards from more than one department or agency, therefore the unique company count will be greater than 67.





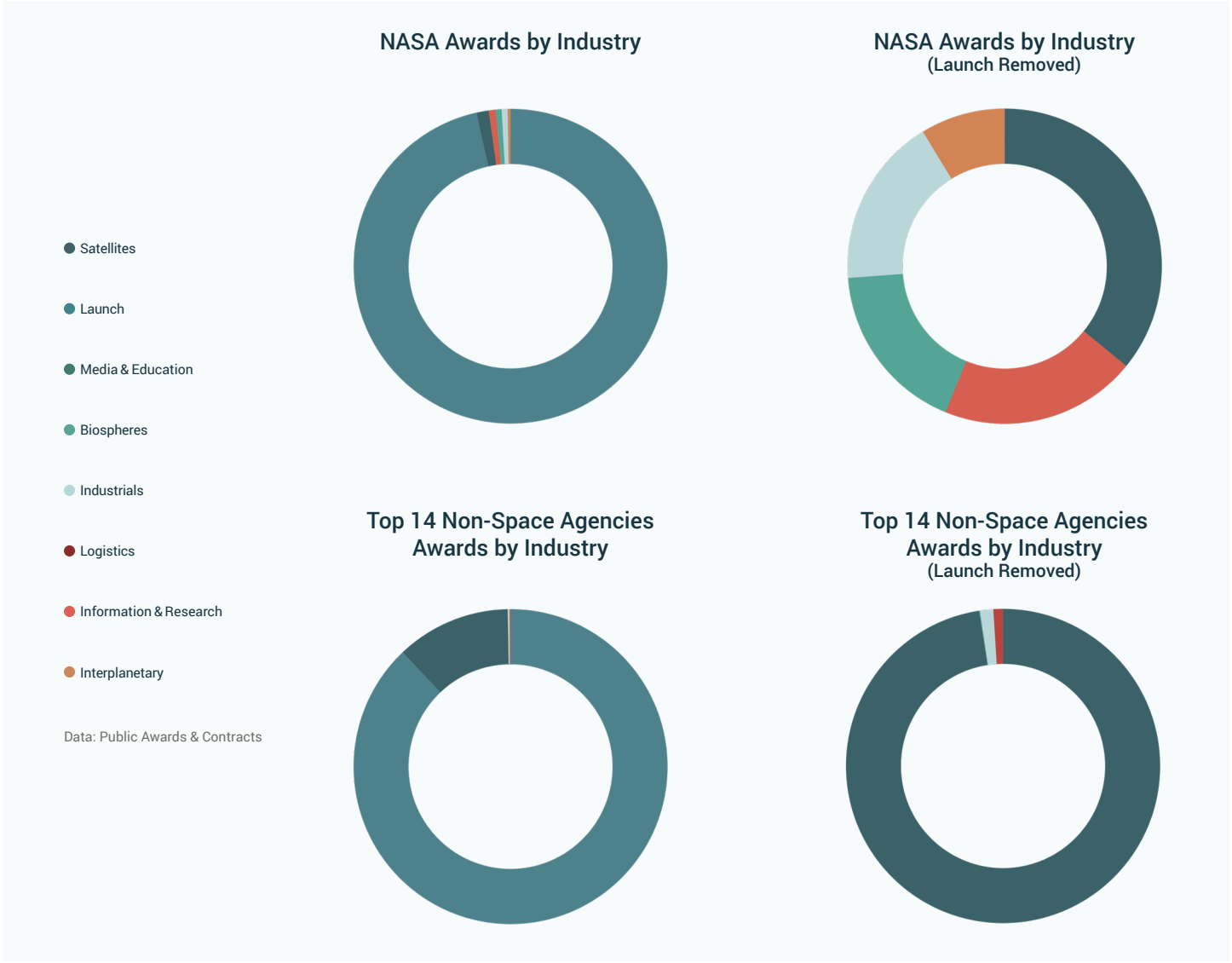
The public funding awarded to companies in our sample has increased 2.1x on average each year since 2000. But this rise is largely attributed to two Launch companies, SpaceX and Blue Origin, whose $6.7B public funding (or 93% of the total sample) exaggerates the growth trend. Removing SpaceX and Blue Origin and looking at the average public funding awarded per company, the average year-over-year increase is 0.5x.





By segmenting the data by industry, it can be seen that the Launch industry has received the largest amount of public funding. By removing Launch, a smaller and more dynamic sample of approximately $400M in public funding is uncovered. This narrower sample shows that the Satellite industry was the earliest and largest recipient of public funding after Launch, beginning in 2002. The Industrials industry has rapidly grown and accounted for 28% of public funding in 2018, consistent with NASA[17] and DARPA[18] stated interest in developing on-orbit manufacturing among other capabilities. The most recent industry to show an increase in public funding is Interplanetary, which accounted for 20% in 2018, again in-line with the NSpC's Space Policy Directive-1: Reinvigorating America's Human Space Exploration Program[19], which has emerged as NASA's CLPS program.[20]

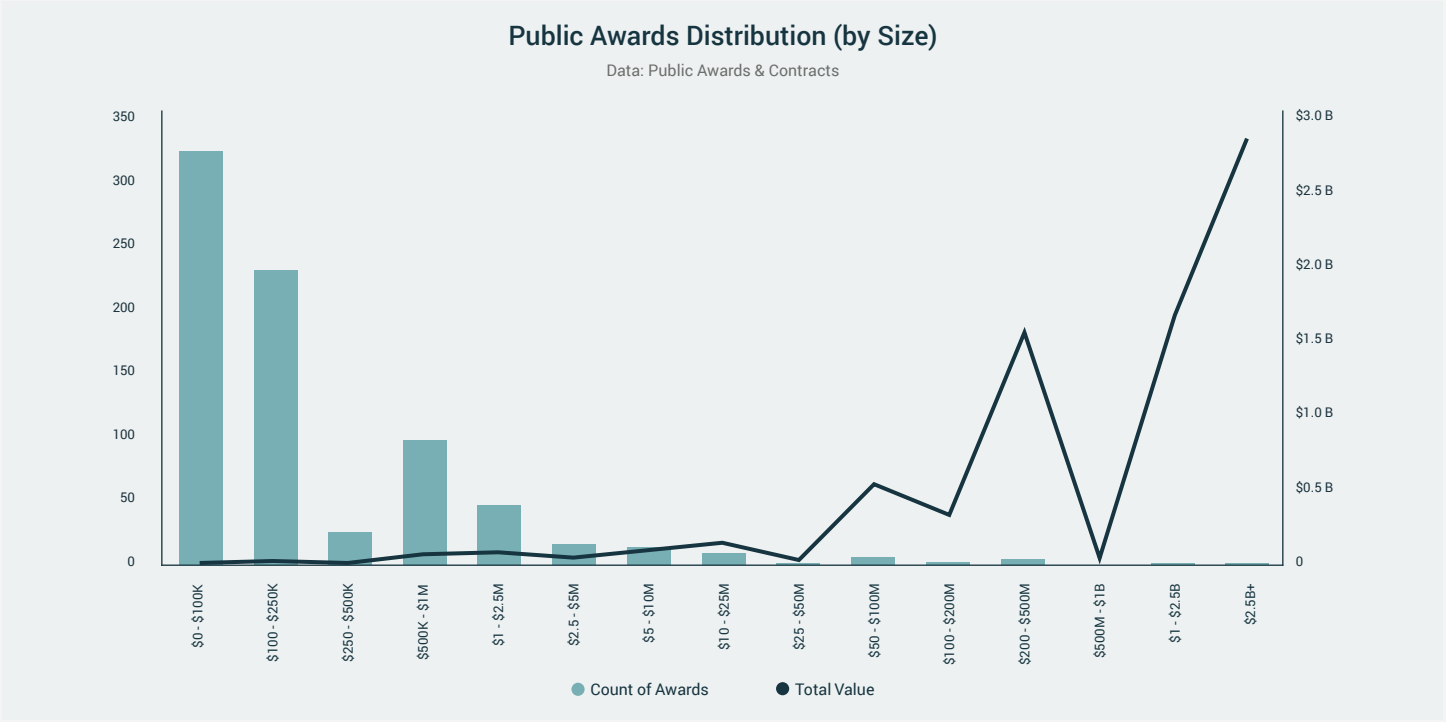
17. In-space Robotic Manufacturing and Assembly, Space Technology Mission Directorate, NASA, November 5, 2018
18. Robotic Servicing of Geosynchronous Satellites, DARPA, Joseph Parrish
19. Reinvigorating America's Human Space Exploration Program, Presidential Memoranda, December 11, 2017
20. NASA Expands Plans for Moon Exploration, NASA, November 30, 2018



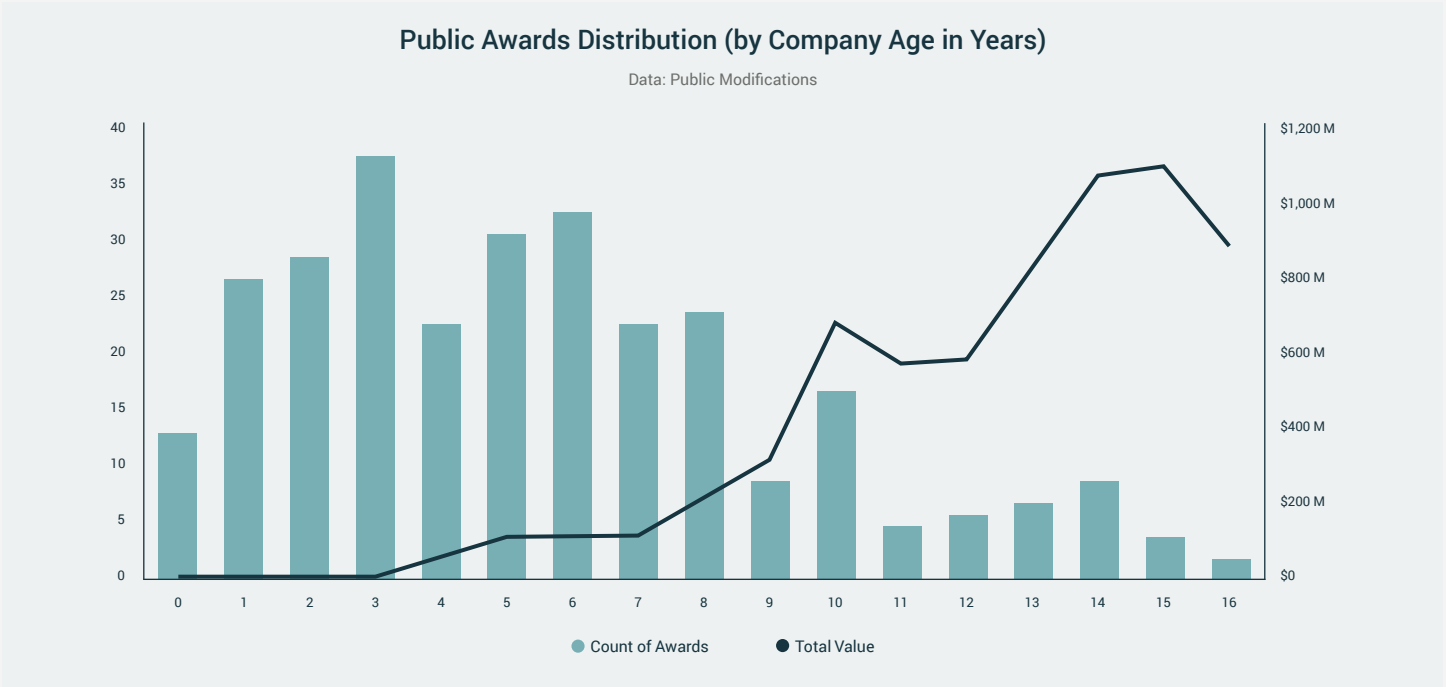
The vast majority of NASA funding for entrepreneurial space companies has gone to the Launch industry , and the Medium and Heavy-lift sectors.[21] Removing Launch, Satellites received the majority of funding (36%) followed by Information & Research (20%), Biospheres (18%), and Industrials (17%). The logistics industry has received limited public funding, however, as activity in Low-Earth Orbit increases, Space Situational Awareness (SSA) is becoming an important resource for managing and protecting assets on-orbit. In 2015, the DOD planned to spend $6 billion on efforts to monitor the space environment in real time through 2020.[22] This research did not identify any public funding going to entrepreneurial space companies within that industry.[23]

When we look at funding from sources other than NASA, again the analysis indicates that the Launch industry received the majority of public funding. While the Medium and Heavy-lift sectors were the biggest recipients, seven Small Launch companies also received funding. Removing Launch, nearly all other funding has gone to the Satellite industry, indicating that NASA is the primary actor supporting the development of technology across the Biospheres, Industrials, and Interplanetary industries.

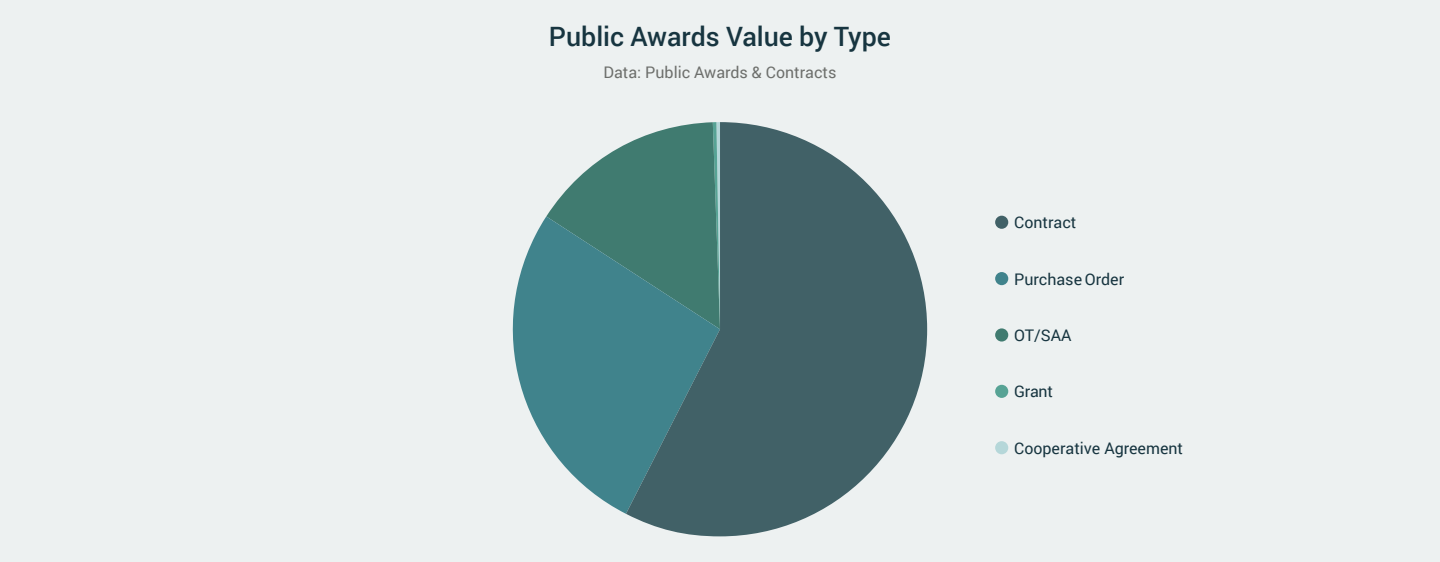
21. See "Industry Segmentation" in Methodology section
22. U.S. Plans $6 Billion Investment in Space Situational Awareness, Space News, October 19, 2015
23. Air Force Launches Defense Technology Accelerator, FCW.com, Sean Carberry, November 29, 2016



The public funding distribution was analyzed by award size, count, and combined value. This identified that the U.S. Government has two primary methods of funding entrepreneurial space companies: 1) a large number of low value awards and 2) a small number of high value awards. The high value awards have all gone to Launch, while the large number of low value awards support technology development and early market traction in across the nascent industries mentioned above. Looking at the underlying data, the difference can largely be explained by the difference in Research & Development (R&D) awards with Service-type contracts.



Continuing this analysis with the public funding distribution by company age, the data indicates that the large number of low-value awards are helping to fund companies during the first eight years of their life, followed by fewer high-value awards. This data reinforces the difference in R&D awards vs. Service type contacts mentioned above.



The U.S. government provides public funding using a mix of contract and other award types. Some of the more commonly used award types and examples are outlined below:

Contracts are the largest public funding award by type, accounting for $4.1 billion, or 58%, of the sample. Types of Contracts include: Firm Fixed Price, Cost Plus Fixed Fee, Definitive Contract (DCA), and Indefinite Delivery Contract (IDC). Of the total $4.1 billion of Contracts, the top three are Indefinite Delivery Contracts from NASA to SpaceX, which accounted for $3.3 billion. The next four largest contracts also went to SpaceX from the DOD USAF/AFRL utilizing Definitive Contracts, which accounted for another $400 million.

Purchase Orders (PO) are the second largest public funding award by type and accounted for $1.9 billion, or 27% of public funding awarded by type. The most common type of PO is a Delivery Order (DO). The largest PO was a DO awarded by NASA to SpaceX for $1.6 billion for R&D Engineering (Commercialized).

NASA and the DoD have the authority to enter into a range of other transactions that accounted for $1.1 billion, or 14%. including Funded Space Act Agreements (SAAs) which make up 90% of the OTs tracked in this sample. NASA enters into SAAs with various partners to advance its mission and program objectives, including international cooperative space activities.[24] Examples of SAAs include: Commercial Orbital Transportation Services (COTS)- a NASA program to coordinate the delivery of crew and cargo to the International Space Station by private companies[25], and Commercial Crew Development (CCDev) - a multiphase, space technology development program that is funded by the U.S. government and administered by NASA, intended to stimulate development of privately operated crew vehicles to be launched to Earth orbit.[26]

Grants account for $32 million, or 0.5% of total public funding by award type and help de-risk emerging technologies and businesses. These are primarily used by DARPA and the NASA Institute for Advanced Concepts (NIAC). The largest grant in our sample was from DARPA to Masten Space Systems for R&D. NIAC is a NASA program for development of far reaching, long-term advanced concepts by “creating breakthroughs, radically better or entirely new aerospace concepts”.[27] The program uses grants to kickstart technology development with Phase I concepts having a Technology Readiness Level (TRL) of 2 or lower.[28] Phase I studies are for nine-month efforts to explore the overall viability of visionary concepts. Phase II studies further develop the most promising Phase I concepts for up to two years and explore potential infusion options within NASA and beyond.[29]

Building on this initial analysis, there is an opportunity to further evaluate alternative types of support not covered in this report including non-reimbursable agreements, government equity investments (e.g. IQT), technology transfers through patents and software licensing, strategic hiring of government employees by entrepreneurial firms, among other forms of support.

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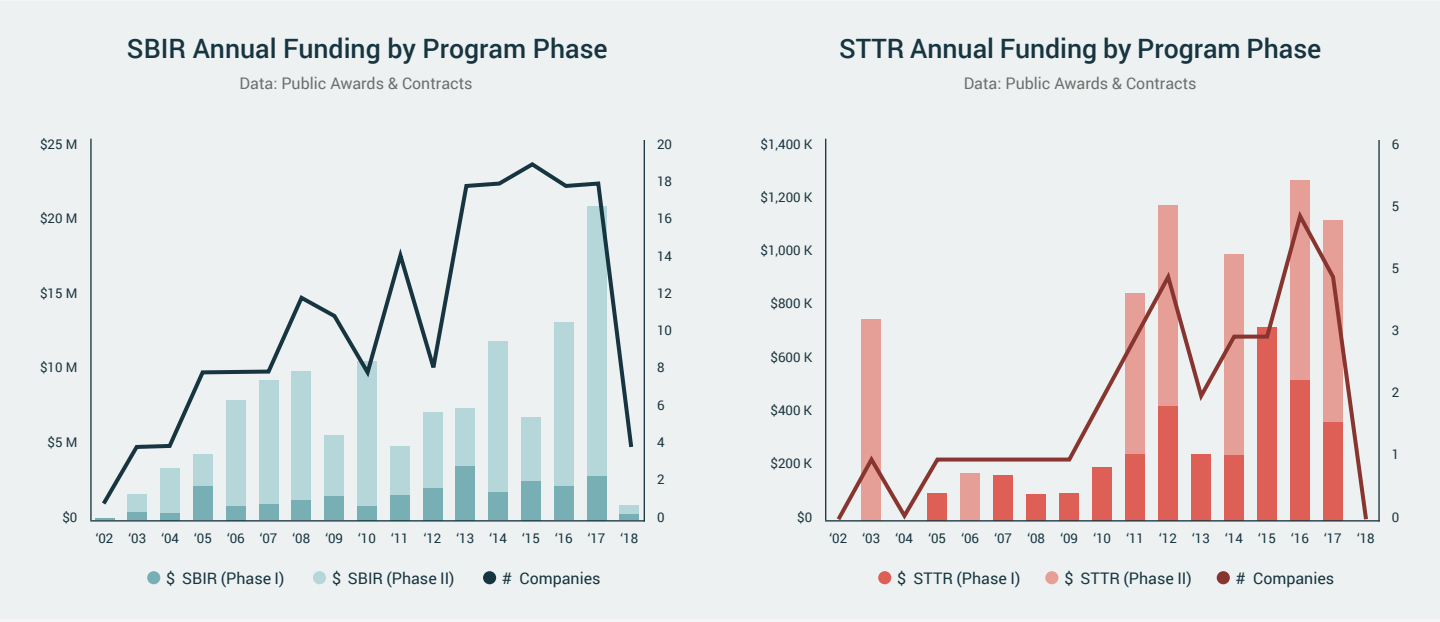
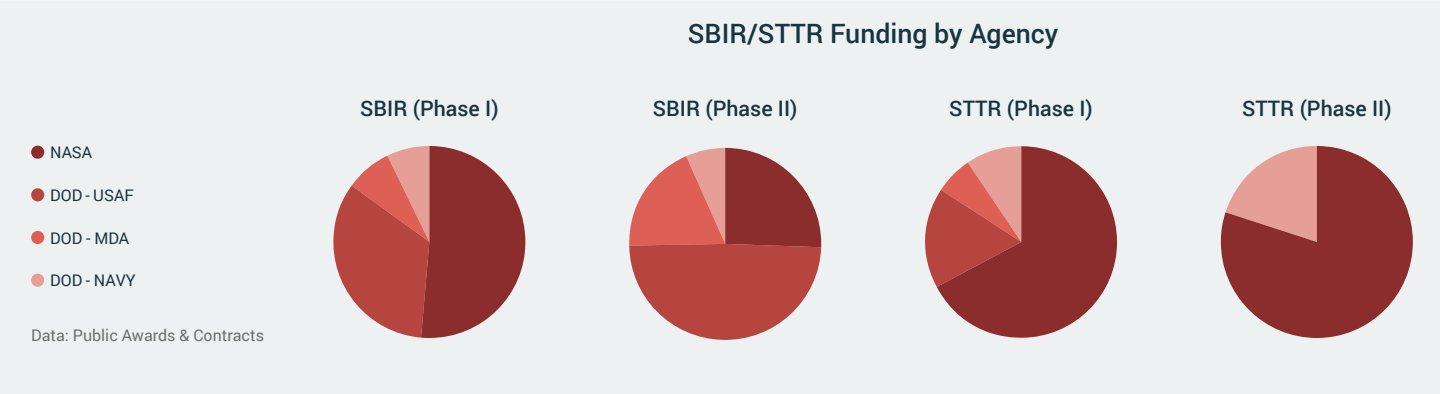
24. NASA Space Act Agreements, NASA Partnerships, Accessed January 12, 2019
25. NASA Releases COTS Final Report (Press release), NASA, June 2, 2014
26. Commercial Crew & Cargo Program Office, NASA, June 3, 2014
27. NASA Innovative Advanced Concepts (PDF) (AIAA 2013-5376). September 10, 2013
28. How to Apply to NIAC, NASA.gov, Accessed January 12, 2019
29. NASA Innovative Advanced Concepts (PDF) (AIAA 2013-5376). September 10, 2013

SBIR/STTR FUNDING ANALYSIS

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs are the most common forms of public funding for entrepreneurial space companies that are eight years and younger, accounting for 44% of all awards in this sample. This funding acts as an important source of non-dilutive, early-stage capital and has provided over $135M in public funding across 345 unique awards to 35 companies (more than half of the sample) located in 27 different states between 2002 and 2018.

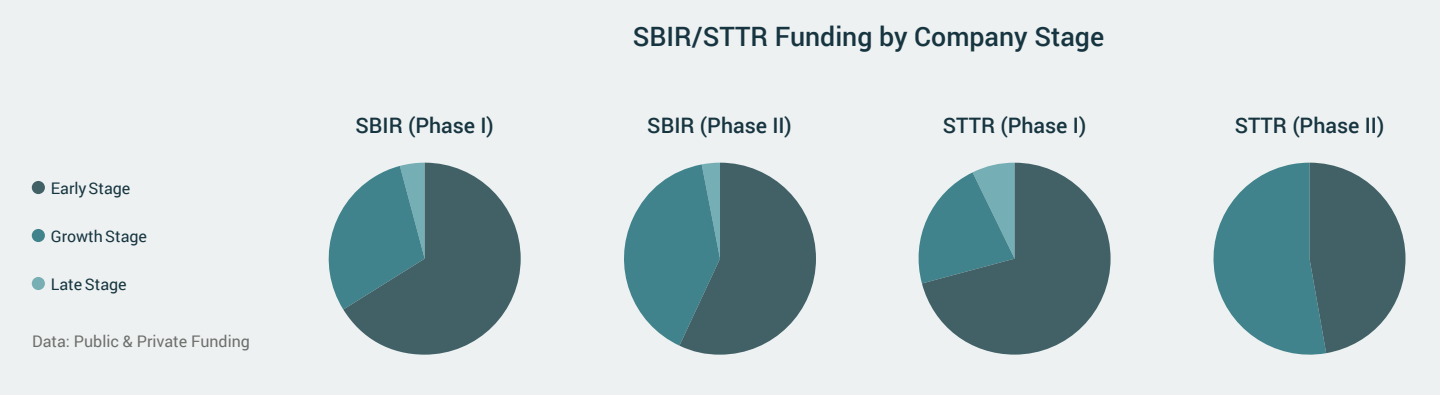


Looking at annual funding, the total value of SBIRs awarded grew on average 20% per year between 2006 and 2017. STTR awards increased on average 50% per year across both Phase I and II awards since 2011. Legislation in 2011 mandated an increase in the amount of money agencies spent on SBIR every year until 2017 and so may be supporting an increase in funds to entrepreneurial space companies.[30]



NASA and the USAF have awarded the largest share of SBIR awards, with NASA awarding the majority of Phase I contracts and USAF awarding the majority of Phase II contracts. It may be worth noting that the USAF has a direct to Phase II authority in their program that NASA does not have, which could help explain the difference between Phase I and II awards.[31] STTR awards are primarily awarded by NASA across both Phases I and II.

30. SBIR/STTR Reauthorization Act of 2011, Congress.gov, December 31, 2011
31. Direct to Phase II Proposal Instructions, Under Secretary of Defense For Acquisition, Tech, and Logistics, Accessed February 25, 2019
**All 2018 data on this page is based on data available through Q3.



Analyzing the percentage of SBIR/STTR funding by company stage, Phase I is primarily comprised of early-stage companies (max private investment round of $10M), which is expected since both SBIR and STTR funding supports small businesses with less than 500 employees. Further, growth stage companies (max private investment round of $80M) receive a larger proportion of Phase II awards, which was expected, but may also suggest that Phase I awards support the fundraising efforts of entrepreneurial space companies by sending a positive signal to investors. This quote from a seed stage satellite component manufacturing company personalizes the effect that public funding can have:

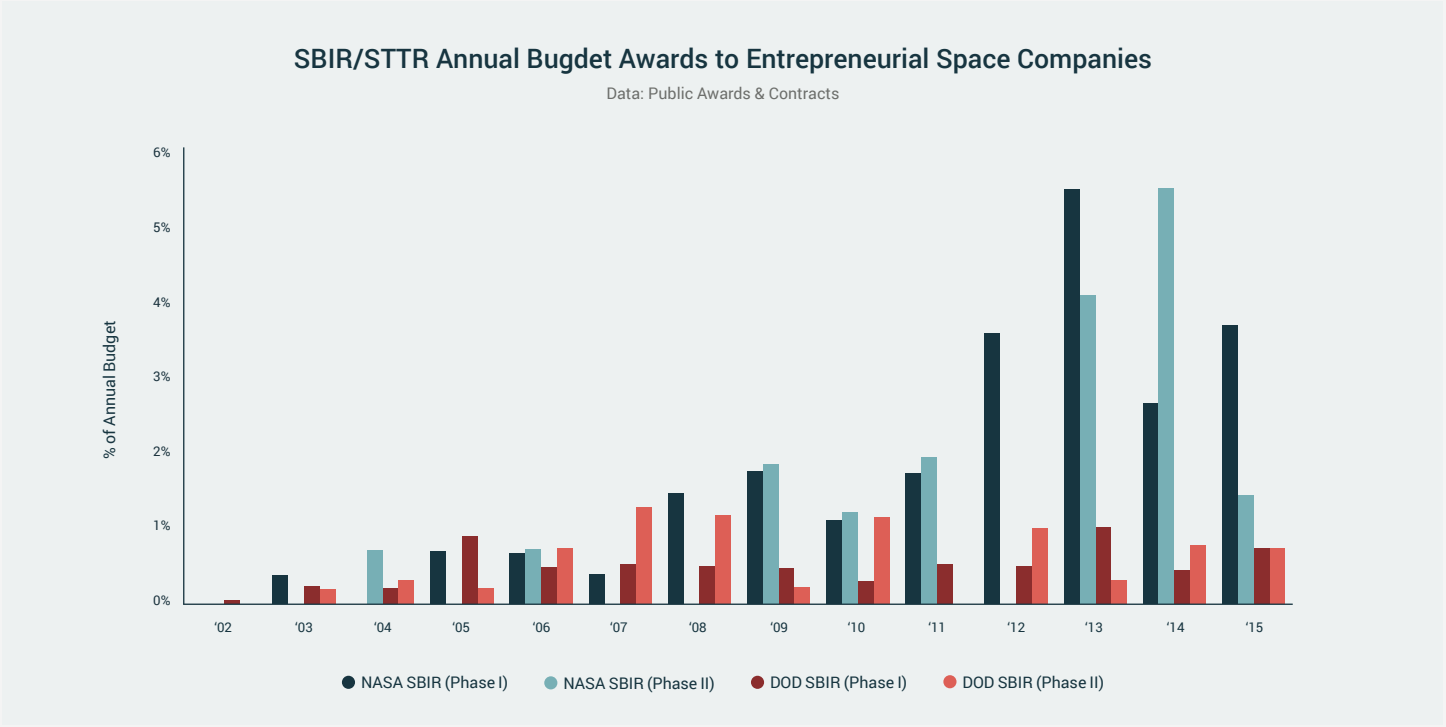
> "An early DARPA contract gave us the credibility we needed to raise our seed round … endorsements from organizations that investors trust (NASA, DARPA, USAF, etc.) have had a positive impact on our business."

TABLE 5 - SBIR / STTR AWARDS ANALYSIS

Data: Public Awards & Contracts

SUMMARY STATISTICS	SBIR (PHASE I)	SBIR (PHASE II)	STTR (PHASE I)	STTR (PHASE II)	SBIR/STTR TOTAL	ALL AWARDS TOTAL
Number of Awards	222	86	30	7	345	782
Total Value of Awards	$26.5M	$99.2M	$3.5M	$4.5M	$133.7M	$7.2B
Company Count per Phase	32	20	10	4	66	–
Total Private Funding Raised	$392.3M	$256.4M	$83.9M	$84.7M	$817.3M	$7.9B
Average Private Funding per Company	$12.3M	$12.8M	$8.4M	$21.2M	$12.4M	$117.5M
Share of Total Public Funding Number	28.1%	10.9%	3.8%	0.9%	43.7%	100.0%
Share of Total Public Funding Value	0.4%	1.4%	0.0%	0.1%	1.9%	100.0%
Private Funding Multiple ($Private/$Public)	15.0x	3.0x	24.0x	19.0x	6.0x	1.1x

By combining public and private funding data, it is possible to calculate the amount of private capital that entrepreneurial companies funded by SBIR/STTR were able to attract, relative to each dollar of public funding they received. The 35 unique companies (52% of the Public Awards and Contracts sample) that received SBIR/STTR awards were able to attract over $817M in private capital, or $6 of private investment for every $1 of public funding. This is significantly more than in comparison to the complete set of 67 entrepreneurial space companies that received some form of government funding, which raised on average $1.1 of private funding for every $1 of public funding. Companies that received SBIR Phase I awards attracted 15x of private funding (more than $392M in equity financing), while companies that received SBIR Phase II awards attracted 3x of private funding (over $256M in equity financing) to help these companies grow and scale commercially. Companies that received STTR awards were able to attract even larger multiples of private funding: 24x and 19x for Phase I and Phase II respectively, but accounted for just 0.1% of total awards in this sample.



NASA and the DOD have awarded, on average, 2% and 1% of their annual SBIR / STTR budget to companies in this report, respectively.[32] We can see an increase by NASA in 2013 and 2014 with Phase I and II awards each reaching 5%.

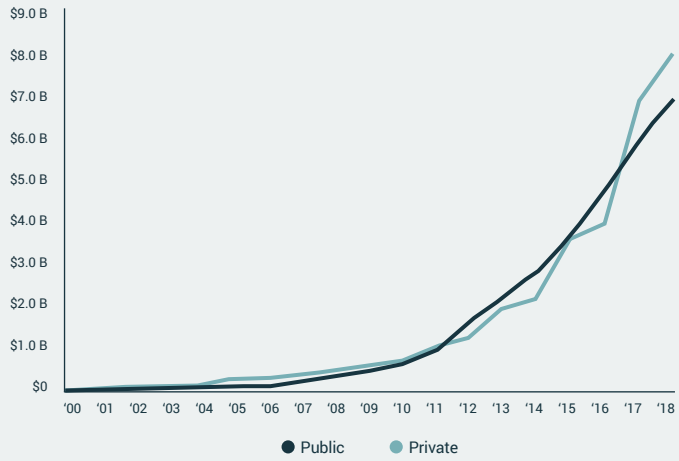
PUBLIC AND PRIVATE FUNDING ANALYSIS

This report is built on an analysis of entrepreneurial companies that have secured non-governmental equity financing. Entrepreneurial space companies that have received both public and private funding, constitutes 31% of the companies tracked in Space Angels' database. This means that the other 69% of U.S.-based companies that have received funding since 2000 are not included in this analysis as they were entirely funded by private capital.

32. Annual Report Files, SBIR.gov

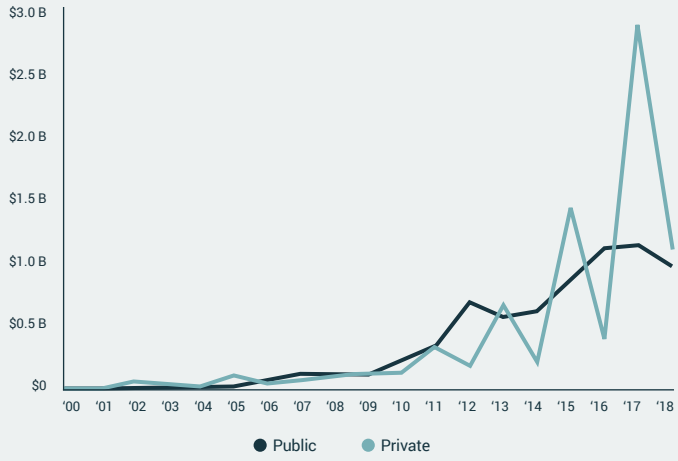
Cumulative Public & Private Funding

Data: Public & Private Funding



Annual Public & Private Funding

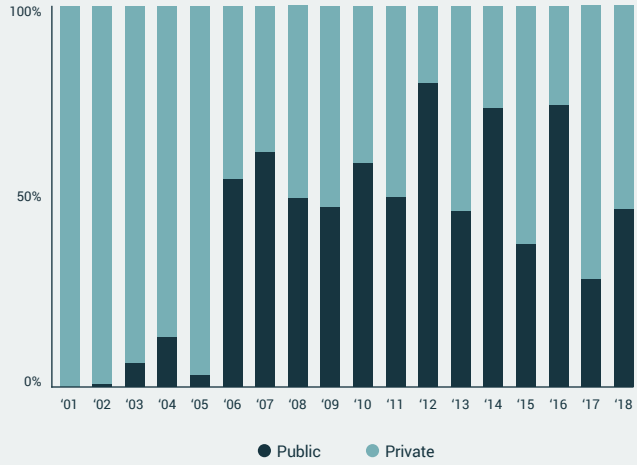
Data: Public & Private Funding



In the Public Funding Analysis section of this report, the data indicated that public funding has been doubling on average each year driven by large service contracts in the Launch industry. Overlaying private funding data, it can be seen that cumulative public and private funding have roughly matched each other since 2000 for companies that receive private financing. However, there is greater volatility in private funding year over year, with significant spikes in 2015 and 2017.

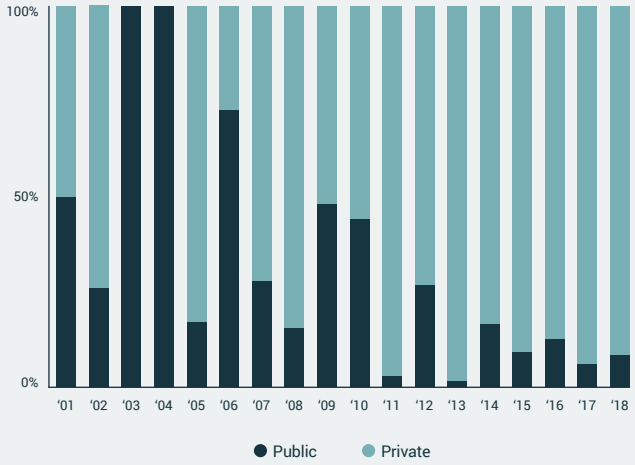
Annual Public & Private Funding Breakdown

Data: Public & Private Funding



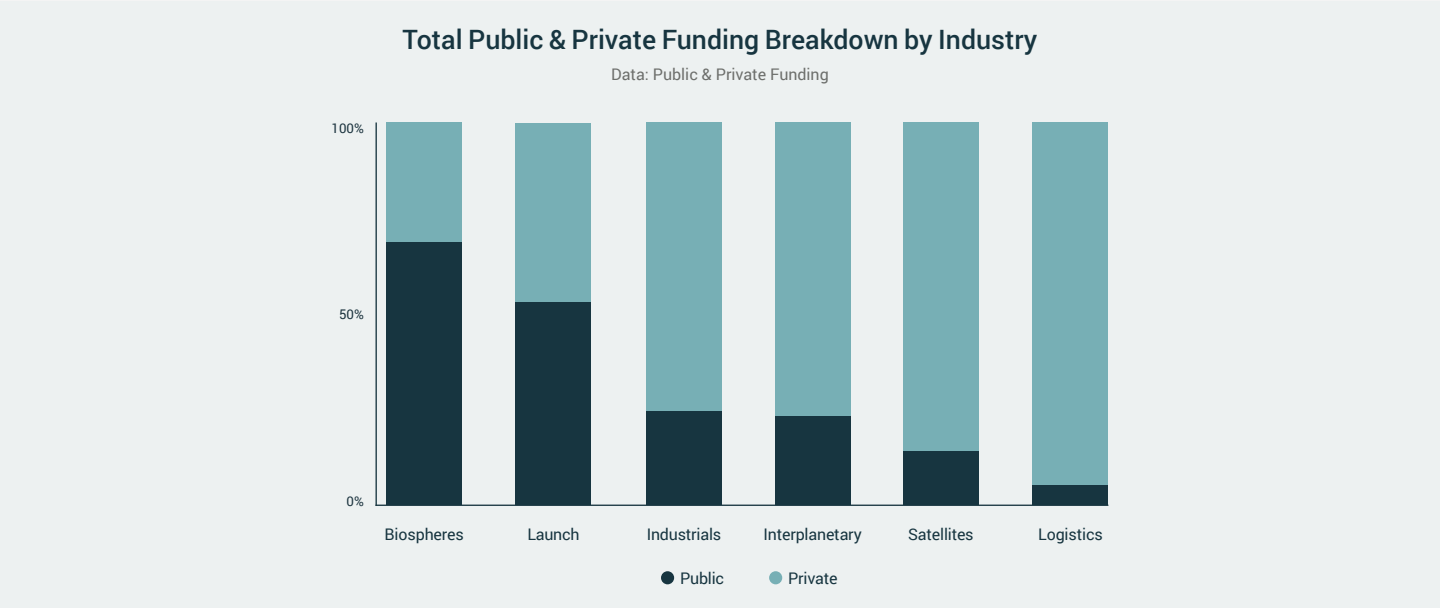
Annual Public & Private Funding Breakdown (SpaceX & Blue Origin Removed)

Data: Public & Private Funding



Analyzing the annual public and private funding data as a percentage of annual investment, the data suggests that public funding has played an increasingly important role from 2006 to present, accounting for 50% or more of total funding each year. With SpaceX and Blue Origin removed, a different pattern emerges. Public funding was a greater percentage of total funding from 2000 to 2006, after which private funding has accounted for an average of 80% of total funding through present.

**All 2018 data on this page is based on data available through Q3.



There is a diverse mix of public and private funding supporting different space industries. The Biospheres and Launch industries have received more than 50% of their capital base from public funding, while Industrials, Interplanetary, Satellites, and Logistics have been largely funded with private capital. There were no companies within Information & Research or the Media & Education industries that received both public and private funding.

TABLE 6 - FUNDING ANALYSIS BY COMPANY STAGE

Data: Public & Private Funding

FUNDING STAGE	EARLY-STAGE	GROWTH-STAGE	LATE STAGE
Maximum Private Funding	$0-$10M	$10 - $80M	$80M+
Number of Companies	29	13	10
Total Number of Awards	222	79	205
Average Awards per Company	7.7	6.1	22.8
Maximum Award	$19.1M 2016 NASA DCA	$3.9M 2006 USAF SBIR (Phase II)	$2,727.6M 2008 NASA IDC
Total Public Funding	$190.1M	$37.0M	$6,680.8M
Total Private Funding	$161.0M	$620.8M	$7,204.0M
Avg Public Funding / Company	$6.6M	$2.9M	$668.1M
Avg Private Funding / Company	$5.6M	$47.8M	$720.4M
Average Company Age	7.5 Years	7.7 Years	11.0 Years
Example Companies	Astrobotic, Made in Space*, NanoRacks*	Firefly Systems, Vector Launch*	SpaceX, Tyvak
Government Agencies	NASA, USAF, DARPA, DOE, NAVY	NASA, USAF, MDA, DARPA, NAVY	ARMY, NASA, USAF, DARPA, NAVY
Common Award Types	DCA - Definitive Contract IDC - Indefinite Delivery CPFF - Cost Plus Fixed Fee	FFP - Firm Fixed Price PO - Purchase Order DCA - Definitive Contract	IDC - Indefinite Delivery DO - Delivery Order DCA - Definitive Contract

Further segmenting the data by stage, the analysis indicates that early-stage companies are different than what Space Angels expected from traditional early-stage venture-backed companies. On average, these companies have raised more public funding than private and are 7.5 years old. Looking at the specific company examples including Astrobotic, Made in Space, and NanoRacks, it becomes clear that a significant portion of these companies are operating in emerging industries (Biospheres, Industrials, and Interplanetary) where public funding may be playing a key role in de-risking technology and supporting early customer traction.

Growth-stage generally consists of Small Launch companies including Firefly Systems and Vector Launch, which have been successful at attracting private capital on the heels of the high-profile success of SpaceX. The two examples highlighted above indicates that these companies raised approximately $100K of public funding for R&D at the early-stage and have now raised over $10M in private funding to scale their businesses.

The late-stage segment generally consists of companies in the established Launch and Satellite industries as these were the two most mature industries and the first to attract private capital in a meaningful way. SpaceX is a large portion of the public funding that these companies have raised, but otherwise the amount of private funding and company age is consistent with expectations for late- stage companies operating outside space, in the more traditional venture/tech market.

While public funding has matched private funding in our sample of 67 companies, there are another 123 equity-financed space companies that have registered for a DUNS number but have not yet secured any public funding. To understand why, Space Angels sent a survey to 16 entrepreneurial companies. Provided below is select feedback from those companies that have worked with multiple government departments. The overall takeaway is a desire to reduce qualification, enrollment and administrative burden, emphasize technical requirements of a product/service, and allow greater flexibility across contracting agents and methods.

"The current 'streamlined' efforts cost significantly more time and resources than commercial proposals."

"Be very careful about requiring significant cost share for early stage technology development from small companies because the technology and business risks are often not sufficiently reduced for outside capital to provide cost share."

"Fast track service providers to IDIQs so they can sell easier into the government."

"Continue integration of ideas from commercial and private sector partners when developing space policy."

"Shift more of the budget from large acquisitions to commercial services and permit contracting officers to accept commercial license agreement terms more often."

"Remember that startups need to move really quickly, so 6-12 months in government terms needs to be closer to 1-2 months for a startup."

"More opportunities like SpEC (SMC)[33] that allow for immediate, clear access to opportunities."

"The U.S. Government has and continues to play a crucial role in growing innovation in the U.S. To drive innovation further, the government should avoid telling companies how to solve a problem, but rather clearly articulate the problem that must be solved, providing clear top-level requirements that companies respond to."

CONCLUSION

Government funding has played a role in the development of the Entrepreneurial Space Age and continues to shape its future. By supporting the development and acting as a customer of SpaceX, the government has helped address a barrier to entry and increased access to the space economy through low-cost, reliable, commercial launch. This paper describes how the government continues to fuel the growth of the Entrepreneurial Space Age in established industries like Launch, while supporting new companies in emerging industries like Logistics and Interplanetary.

The purpose of this research is to better understand the relationship between the U.S. Government and these newer space companies, particularly focusing on the sources, tools, and impact of public funding.

33. Space Enterprise Consortium. Accessed May 07, 2019

The major findings from this report include:

- The total value of U.S. public funding received by entrepreneurial space companies from 2000 through 2018 was $7.2B across 67 companies.

- Public funding has played an important role in supporting an entrepreneurial approach to space, particularly in addressing the barriers to entry, with 93% of U.S. Government funding flowing into the Launch industry.

- NASA is supporting technology development and providing early customer traction across the space economy. While the vast majority of public funding from U.S. Government agencies has focused on the Launch industry, NASA has also awarded funds to companies in the Biospheres, Industrials, and Interplanetary industries.

- Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs awards are the most common forms of public funding for entrepreneurial space companies that are eight years and younger, accounting for 44% of all awards. This funding acted as a source of non-dilutive, early-stage capital and has provided over $135M in public funding across 345 unique awards to 35 companies located in 27 different U.S. states between 2002 and 2018.

- Department of Defense (DOD), Department of Energy (DOE), and NASA's SBIR / STTR programs tend to support entrepreneurial space companies earlier in their life cycle. On average, the 35 companies who received SBIR/ STTR funding attracted $6 in private investment for every $1 of public funding. Comparatively, the complete set of 67 entrepreneurial space companies that received awards from the government averaged $1.1 of private investment for every $1 of public funding.

- NASA and the DOD have awarded, on average, 2% and 1% of their annual SBIR / STTR budget to equity-backed entrepreneurial space companies, respectively.

- There are 123 equity-financed space companies that have registered for a Data Universal Numbering System (DUNS) number but have yet to secure public funding.

It is important to note that the ways in which the U.S. Government supports the further development of space are dynamic and are ever-changing. While this report explores the trends in government support for entrepreneurial space over the past 18 years, recent announcements from NASA and other funding organizations point to changes on the horizon in the way the government interacts with entrepreneurial space companies. At the earlier-stage, the USAF's new AFWERX SBIR program— which improves upon the traditional SBIR program by shortening the awards cycle, better connecting government end users, and structured the agreement as a purchase order instead of a sub contract—was recently allocated $10m[34] of the total USAF SBIR budget. Both JPL[35] and the USAF[36] have started accelerator programs in partnership with Techstars, pointing to the government's increasing interest in exploring collaboration with early-stage entrepreneurial companies. Meanwhile, at the later stages, recent announcements like the NASA CLPS program that selected nine companies—four of which were in the scope of this research—to award up to $2.6B in contracts to over the next 10 years[37], points to NASA's growing interest in working with entrepreneurial space companies.

As this is a preliminary analysis, the scope of this research was limited to create a baseline. Space Angels sees additional opportunities to explore different types of support not covered in this report including non-reimbursable support, government equity investments, technology transfers, and strategic hiring, among other types of support; evaluate state and local initiatives designed to attract or enable space activities; and analyze international programs designed to advance of their national space industries.

ACKNOWLEDGMENTS

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34. Air Force Accelerating Acquisition with AFWERX, National Defense, Accessed: May 07, 2019
35. Techstars and Starburst Aerospace are launching a space industry accelerator in Los Angeles, TechCrunch, Accessed: Feb 12, 2019
36. Air Force Accelerator Powered by Techstars, Techstars, Accessed: Jan 4, 2019
37. NASA Chooses Private Companies for Future Moon Landings, New York Times, Nov 29, 2018